
A preliminary *in vitro* study of the incidence and position of the root canal isthmus in maxillary and mandibular first molars

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Abstract

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Aim To investigate *in vitro* the incidence and position of the root canal isthmus in extracted mesiobuccal roots of maxillary and mesial roots of mandibular first molars.

Methodology Fifty maxillary and 50 mandibular molars were included in the study. The mesiobuccal roots of maxillary molars and the mesial roots of mandibular molars were sectioned from their crowns in the furcation region and embedded in clear resin. Transverse serial 1-mm-thick sections from the apical 6 mm were prepared. The apical side of each section was stained with India ink and observed through a light microscope. The sample images were saved to disk using a digital camera and the root canals in terms of the number present and the incidence and classification of isthmuses.

Results In the mesiobuccal root of the maxillary first molars, 70% had one canal, whereas 29.5% had two canals. In the mesial root of mandibular molars, 41% had one canal, whereas 59% had two canals. In some sections, more than two canals were found close to the apical foramen. The isthmus incidence was greatest 3–5 mm from the apex. In teeth having two canals, a complete or partial isthmus was frequently observed in the sections between 3 and 4 mm from the apex. Of the isthmuses present, 22% were complete and 37% partial in mandibular molars and 17.3% were complete and 11.7% partial in maxillary molars.

Conclusions The incidence of isthmus in the mesiobuccal root of the maxillary first molars and in the mesial root of the mandibular first molars was high, particularly in sections 3–5 mm from the apex. Cleaning the isthmus is a major challenge during root canal treatment.

Keywords: anatomy, endodontics, incidence, isthmus.

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Introduction

The success rate of surgical endodontics varies between teeth. Friedman *et al.* (1991) reported successful results in only 44.1% of premolars and molars, whereas others (Altonen & Mattita 1976, Persson 1982, Ioannides & Borsilap 1983) have reported a 71–73% success rate for apicoectomized molars. However, successful treatment in

anterior teeth is generally higher (Ingle 1965, Storms 1969, Harty *et al.* 1970).

The maxillary first molar and its mesiobuccal root are often treated surgically (Rapp *et al.* 1991). However, the success rate in these teeth is lower than that of the mandibular first molar following surgery (Nordenram & Svardstrom 1970). The differences between the teeth may be due to anatomical factors.

An isthmus is a narrow, ribbon-shaped communication between two root canals that contains pulpal tissue. It is also known as a corridor (Green 1973), a lateral interconnection (Pineda 1973), or a transverse anastomosis (Vertucci 1984). Any root containing two canals has a high incidence of isthmuses. Pineda (1973) showed

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interconnections in 4.9% of the roots examined, rather lower than the 16% reported by Green (1973) and the 30.1% reported by Cambruzzi & Marshall (1983). Vertucci (1984) reported that isthmuses occurred in 52% of roots and two canals. He also stated that 75% of the anastomosis was located in the middle and 15% in the apical third of roots. Weller *et al.* (1995) reported that 40% of the roots of maxillary first molars had one canal, whereas 60% had two canals. The incidence of an isthmus was greatest in the apical 3–5 mm. In teeth with two canals, a complete or partial isthmus was always present in sections at 4 mm from the apex.

A canal isthmus can function as a bacterial reservoir, accounting for the failure of conventional endodontic surgery. The aim of this study was to determine the incidence and location of isthmuses in maxillary and mandibular molars. The type of root canal configuration and the level of canal bifurcation or convergence were also examined.

Materials and methods

Fifty human maxillary and 50 mandibular first molars were randomly selected and stored in 10% formalin. The age, gender, and race of the patients were unknown. The identification of these teeth as maxillary and mandibular first molars was confirmed by accepted criteria (Sicher 1975).

The mesiobuccal crown and root from the maxillary molars were resected in one piece using an ultra-thin separating disk. The first cut was made through the buccal furcation to the palatal root. The second cut was directed through the mesial furcation joining the first cut. The mesial and distal roots of the mandibular molars were divided. The opening into the pulp chamber was sealed with wax in order to prevent embedding material from entering the root canal system.

Each root was separately embedded in clear resin (Crystal, São Paulo, Brazil). Starting at the root apex, six serial transverse 1-mm sections were cut perpendicular to the long axis of the root with a low-speed diamond saw (South Bay Technology Inc., DWH4122, 323190H7, San Clement, CA, USA). Each section was stored in 5.25% sodium hypochlorite for 24 h in order to remove any organic material remaining in the root canals. Each section was rinsed in water and dried. Only the apical side of each section was evaluated.

The resected surface was stained with India ink (Super Nankin Professional – Trident S/A, Itapuí, Brazil) and examined under a stereomicroscope (Lambda Let 2, ATTO Instruments Co., Hong Kong) at 30× magnifica-

tion. The images were stored in a computer using a video camera (LG color camera, CCD digital, Seoul-Tukpyolsi, Korea) and observed with a projector (Pro-screen/Philips 4600, Syncrotape, São Paulo, Brazil) on a white screen.

Using the data projector, two examiners observed each section simultaneously and determined the number of root canals as well as the presence or absence of an isthmus. An isthmus was classified as complete or partial. A complete isthmus had a continuous opening between the two main root canals (Fig. 1). A partial isthmus was classified as a narrow projection of one root canal opening towards the second in the same root section but not merging (Fig. 2). Different anatomical forms of isthmus openings were observed. After all sections were evaluated, the type of canal configuration present in each root was classified according to Hsu & Kim (1997). Type I was defined as either two or three canals with no notable communication. Type II was defined as two canals with a definite connection between the two main canals. Type III differs from Type II due to the presence of three canals instead of two. Incomplete C-shaped

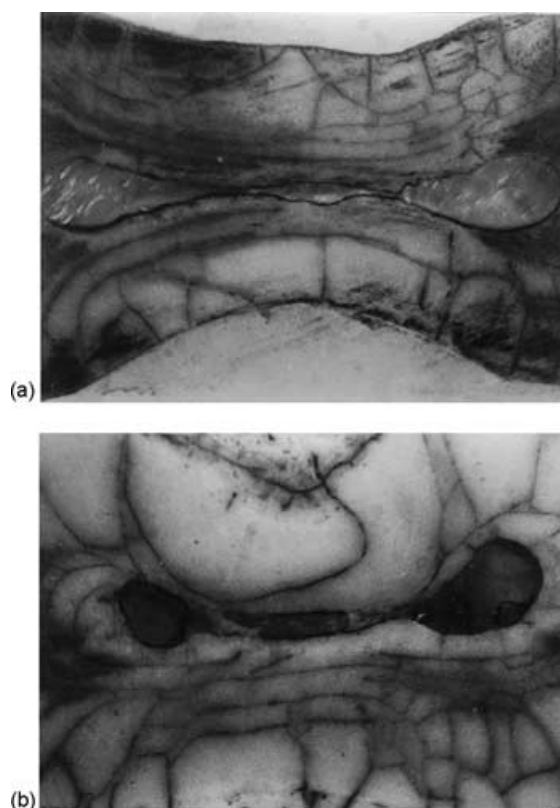


Figure 1 Representative sections with a complete isthmus (original magnification 30×).

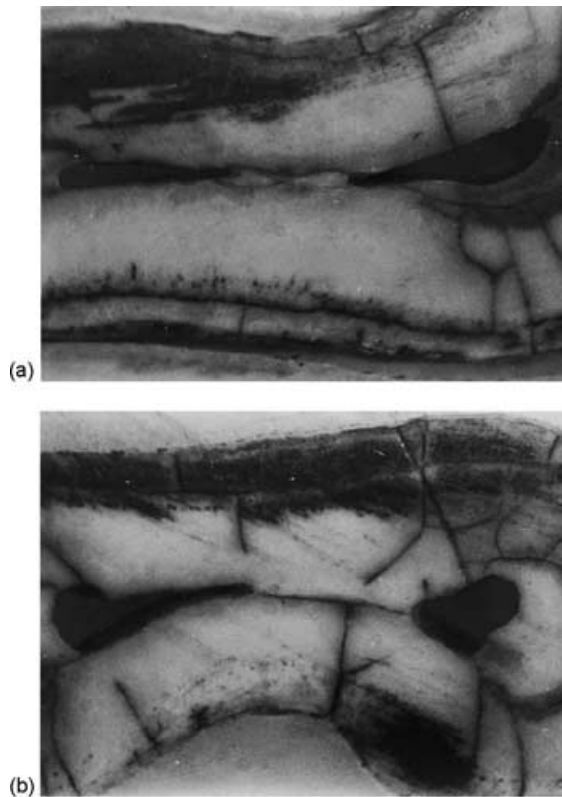


Figure 2 Representative sections with a partial isthmus and two canals (original magnification 30 \times).

canals with three canals were also included in this category. Canals extending to the isthmus area were classified as type IV. Type V was identified as a true connection or corridor throughout the section.

Results

The results are listed in Tables 1 and 2. One root canal was found in 69% of the mesiobuccal maxillary roots examined, and two canals located 6 mm from the apex were present in 31% (Table 1). Of the mesial mandibular

Table 1 Number of canals at each level of the mesiobuccal root of maxillary first molar

Level from apex (mm)	No. with one canal	%	No. with two canals	%	Isthmuses (%)
6	33	69	15	31	23.68
5	31	69	14	31	31.58
4	29	66	15	34	20.0
3	27	64	15	36	11.43
2	25	64	14	36	–
1	10	91	1	9	–

Table 2 Number of canals at each level in the mesial root of mandibular first molar

Level from apex (mm)	No. with one canal	%	No. with two canals	%	Isthmuses (%)
6	16	41	27	59	32.43
5	19	42	26	58	33.33
4	20	46	23	54	30.3
3	24	56	19	44	20.59
2	22	52	20	48	11.9
1	11	91	1	9	6.67

roots, 41% had only one canal and 59% two (Table 2). All of the canals classified as type II converged into one canal 2–4 mm from the apex, whereas in three roots the canals that bifurcated into two separate canals (type IV) were more frequent 3 mm from the root apex.

None of the sections had more than two main root canals. In the maxillary molar group, the incidence of isthmus increased with distance from the apex. In the mesiobuccal root of the maxillary first molars with two canals, the incidence of isthmus at the 2–6 mm level was 15%. The incidence of an isthmus was higher at the apical 3–5 mm level. In the mesial root of the mandibular first molars, the incidence of two canals decreased further from the apex. The greatest incidence of isthmuses was observed at the 3–6 mm level. The frequencies of isthmus types are presented in Figs 3 and 4.

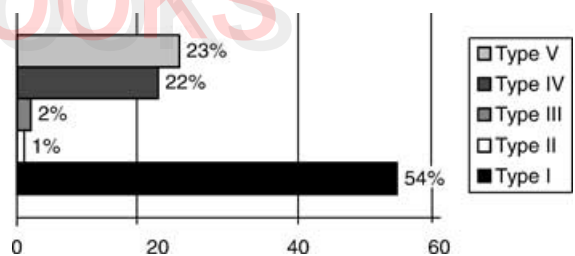


Figure 3 Frequency of isthmus types in mesial roots of first mandibular molars.

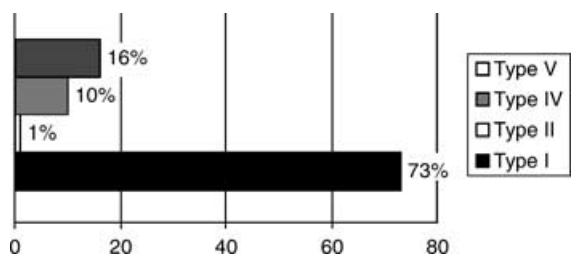


Figure 4 Frequency of isthmus types in mesiobuccal roots of first maxillary molars.

Discussion

The methodology utilized in this study was similar to those used by Weller *et al.* (1995). Each root was embedded separately in clear resin and parallel transverse sections were cut. This method differed from the study by Tam & Yu (2002) where the sections were cut perpendicular to the long axis along the root curvature. Tam & Yu (2002) reported that 18.75% of specimens had a complete isthmus between two canals in sections 3–5 mm from the apex in the mesiobuccal root of maxillary first molars. This is lower than the 30.1% frequency reported by Cambruzzi & Marshall (1983) and the results from the present study (Table 1), but higher than the results of Weller *et al.* (1995), who reported 12.0–14.3% of teeth examined.

Stropko (1999) reported the percentage of second mesiobuccal canals in 1732 conventionally treated maxillary molars, 1096 of which were first molars, 611 second molars, and 25 third molars. A second mesiobuccal canal was found in 93.0% of first molars and 60.4% of second molars with 73.2% of the teeth containing four canals. When surgically treating the mesiobuccal root, it is important to visualize the isthmus that exists between the first and second mesiobuccal canals (Carr 1994). According to Stropko (1999), normal observation of the pulpal floor with the dental operating microscope reveals the isthmus appearing as a thin line, unless it has calcified.

The incidence of a complete isthmus in this study was lower than that reported by Cambruzzi & Marshall (1983) and Vertucci (1984). Cambruzzi & Marshall (1983) examined the bevelled surface of both maxillary first and second molars. Reporting a combined number only, they did not report the incidence of complete isthmuses for each type. Vertucci (1984) examined the entire root canal systems of transparent specimens. Even though he reported a 52% incidence of transverse anastomoses, only 15% were found in the apical third of the root. This agrees more closely to the findings of this study.

The concept of a partial isthmus has not been reported previously. Any openings on the resected root surface may contain microorganisms or necrotic tissue or even act as a portal of exit for a noninstrumented or unfilled part of the root canal system.

There were many more sections at each level of the root containing a partial isthmus than a complete isthmus (Fig. 1). Whenever any part of the mesiobuccal root is resected, and two main canals are located, the presence of an isthmus should be expected and the area

between the two canals should always be prepared and sealed with a root end filling.

In the past, not only was the canal isthmus often overlooked, but it was also very difficult to prepare if located. Currently, with the advent of microscopic endodontic surgical techniques, it is possible to visualise the resected root surface and identify the isthmus, prepare it with ultrasonic tips, and fill it with appropriated materials. The recognition and treatment of the canal isthmus may be one factor that will reduce the failure rate of endodontic surgery (Hsu & Kim 1997).

Conclusions

The isthmus incidence in the mesiobuccal root of the maxillary first molars and in the mesial root of mandibular first molars was high, particularly 3–5 mm from the apex. A complete or partial isthmus was frequently observed in teeth having two canals demonstrating that this anatomic structure should be considerate clinically.

Acknowledgements

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